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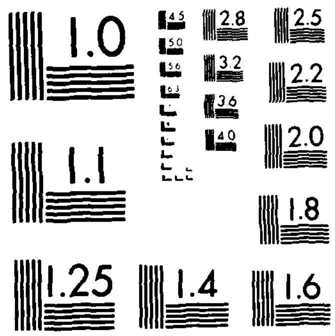


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FINAL REPORT

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SATELLITE MEASUREMENTS OF ATMOSPHERIC AEROSOLS

SAIC

Science Applications International Corporation





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SAIC-85/1606

FINAL REPORT

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# SATELLITE MEASUREMENTS OF ATMOSPHERIC AEROSOLS

March 29, 1985

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An error analysis of the two-channel technique has shown that the AVHRR noise will result in root-mean-square errors of about 0.40 in the size distribution parameter $\nu$, and about 0.08N in aerosol content, N. These errors are increased due to the effects of undetected clouds in the field of view and variations in the ocean surface reflectance. Based on an analysis of the Barbados and USNS Hayes data, these environmental errors could be of the same magnitude for $\nu$, and larger for N. However, because of uncertainties in the data set there is uncertainty in these estimates of the environmental errors.

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## SUMMARY

The error analysis of the two-channel technique has shown that the AVHRR noise will result in root-mean-square errors of about 0.40 in $\nu$, and about 0.08N in N. These errors will be increased due to the effects of undetected clouds in the field of view and variations in the ocean surface reflectance. Based on an analysis of the Barbados and USNS Hayes, these environmental errors could be of the same magnitude for $\nu$, and larger for N. However, because of uncertainties in the data set there is uncertainty in these estimates of the environmental errors. An effort was made to obtain a good data set at San Diego to clarify these errors. However that data set was also of uncertain quality due to apparent sun-photometer problems. As a result, further clarification of the environmental errors was not possible.

# 1.0 INTRODUCTION

The investigation of the satellite technique to measure tropospheric aerosols over the ocean has continued with a comparison of predicted errors[1] with measured errors in the Barbados and USNS Hayes NOAA-6 data sets. The data sets obtained at San Diego for NOAA-7 overpasses have been analyzed.

Two papers reporting on the techniques developed in this investigation were presented during 1984. The first was at the XXV COSPAR Meeting in Graz, Austria, July 2-6, 1984, and the second was at the International Radiation Symposium 1984 in Perugia, Italy, August 21-29, 1984.

## 2.0 ERROR ANALYSIS

### 2.1 PREDICTED ERRORS IN N AND $\nu$

The previous report(1) showed that the main error sources that affect the use of the two-channel technique are the unknown atmospheric ozone and water vapor contents and the AVHRR sensor noise; if it is assumed that the ozone and water vapor contents would be known in operational use of the technique, then only the AVHRR sensor noise is of concern.

The Barbados and USNS Hayes (B and H) data set consisting of 32 overpasses is considered to be representative of typical viewing and sun angles and aerosol contents, and in addition, has the only ground-truth measurements of N and $\nu$ for comparison with the AVHRR values. Thus, using the B and H data set for the error analysis also allows the predicted errors to be compared with observed errors. Of the 32 overpasses, only 26 gave solutions(2) with the two-channel analysis, presumably due to errors in the AVHRR radiances, perhaps due to clouds in the field of view.

The results for the single channel (TLU1) analysis and the two channel (TLU2) analysis were given in the previous report(1), but are repeated here, for completeness, in Figs. 1-3.

The deduced error of ±0.05% albedo for the AVHRR noise was applied to each AVHRR channel alone, and then to both at the same time for each of the 26 cases in the B and H data set. It was found that the errors in N and $\nu$ produced by an error in both channels at the same time is approximately equal to the sum of the errors produced by an error in each of the channels alone. Thus, only the results of the error applied independently to each channel are given in Table 1. Also shown in Table 1 are the results for a 3% error in the Channel 2 radiance due to an unknown water vapor content. It should be noted that the same albedo error produces a different error in N and $\nu$ for each of the 26 cases; this is because the dependence of radiance on N and $\nu$ varies with the viewing and sun angles. The root-mean-square values of the errors are summarized in Table 2.

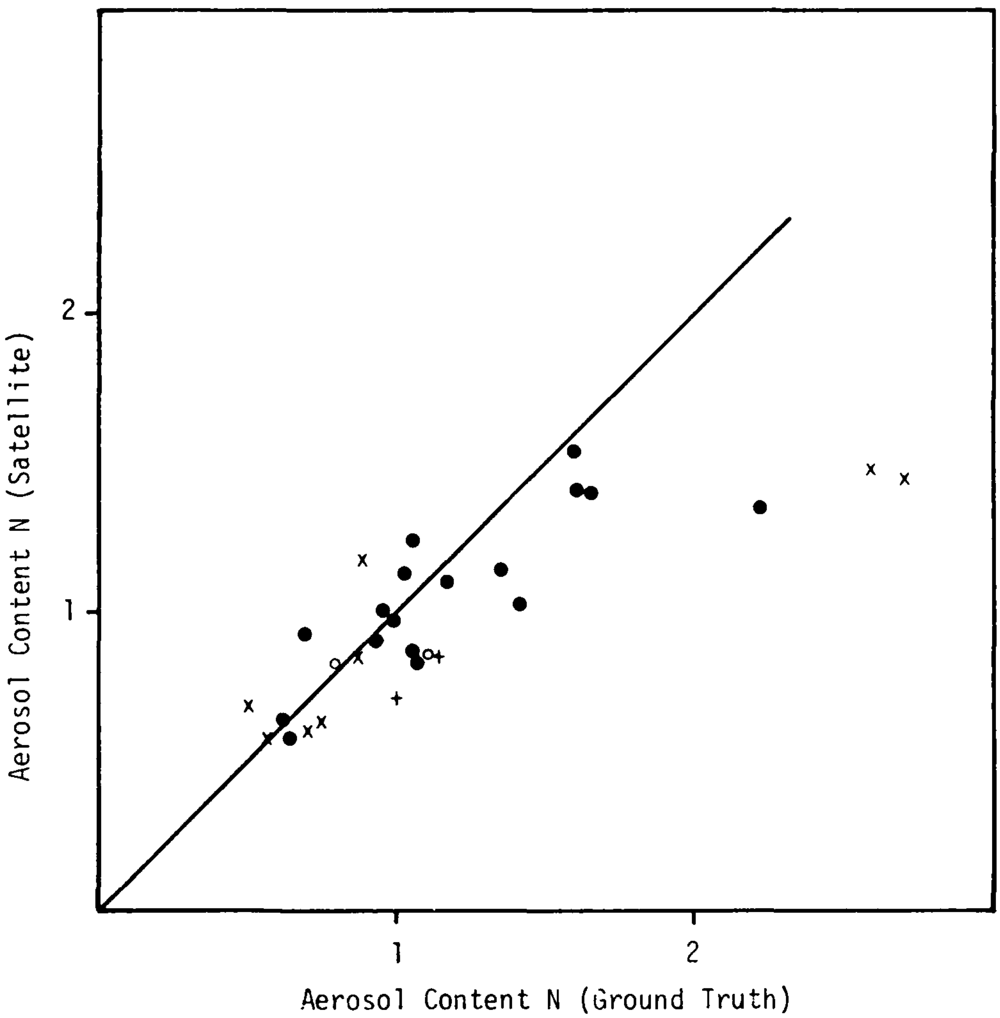


Figure 1. Comparison of Satellite (TLU1) and Adjusted Ground Truth Measurements of Aerosol Content for Barbados, •, (x indicates $\theta_o > 70°$) and for USNS Hayes, ∘, (+ indicates $\theta_o >$ 70°).

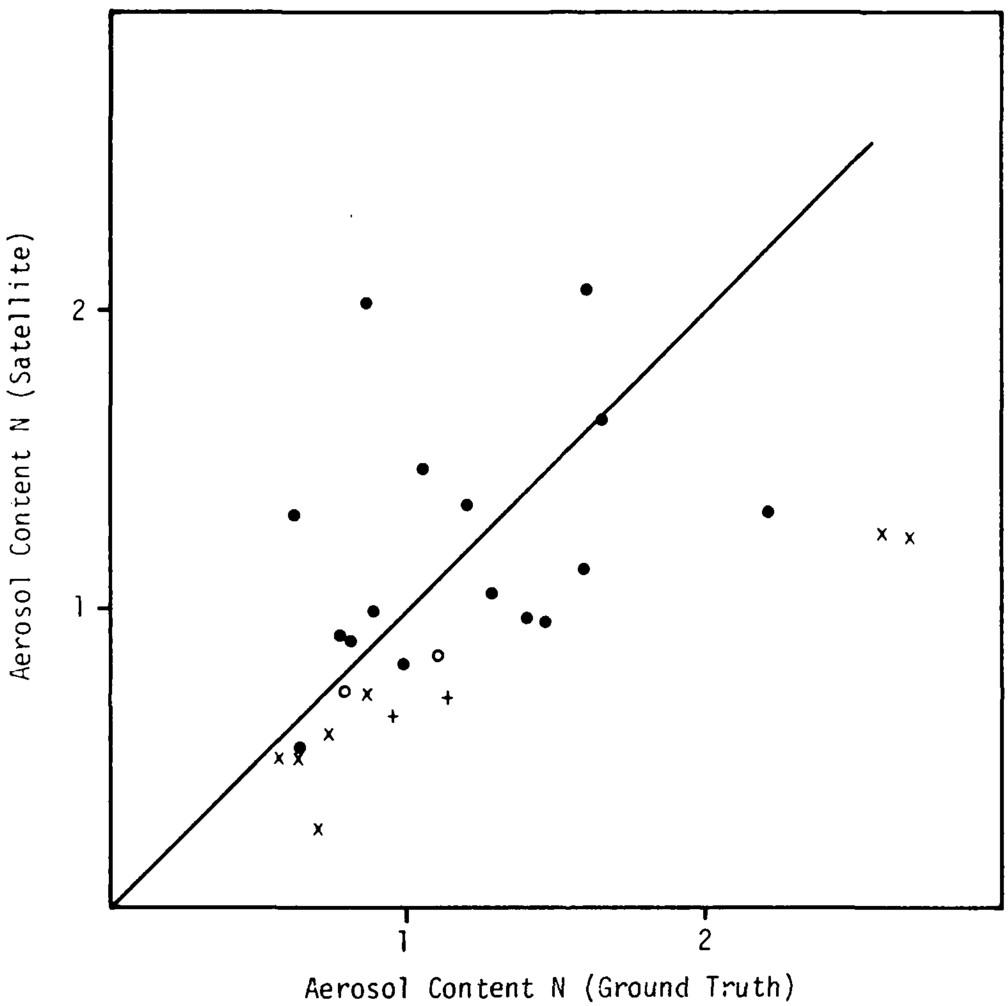


Figure 2. Comparison of Satellite (TLU2) and Ground-Truth Measurements of Aerosol Content [• x ($\theta_o > 70°$) Barbados; o + ($\theta_o > 70°$) USNS Hayes].

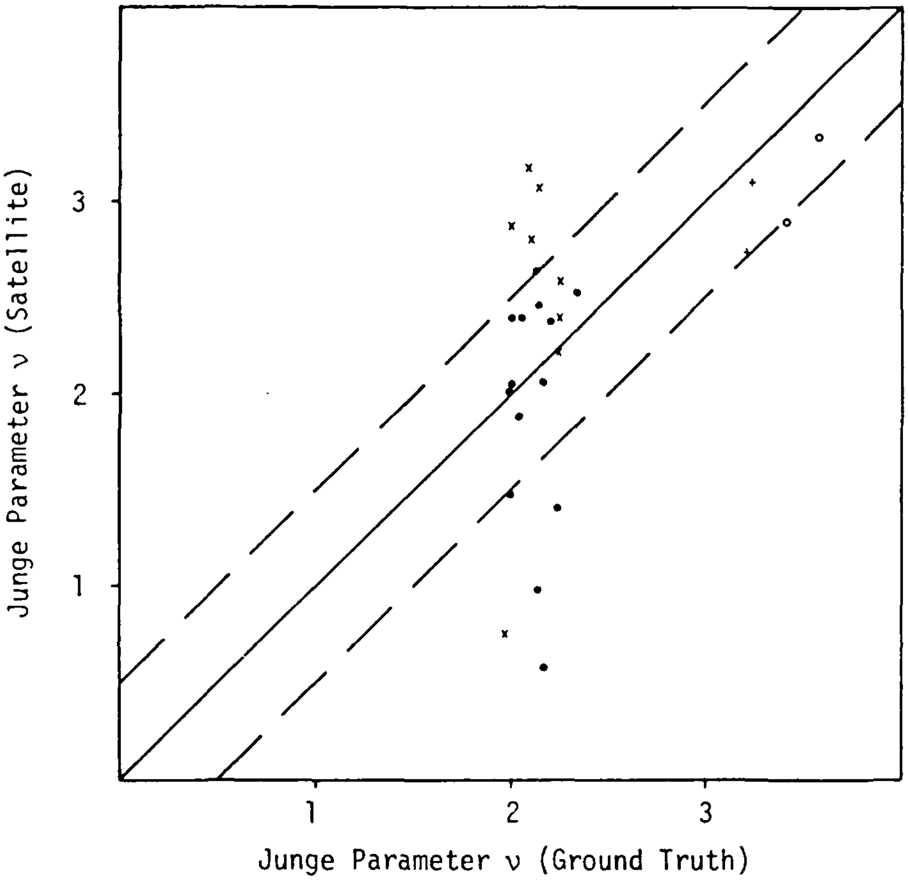


Figure 3. Comparison of Satellite and Ground Truth Measurements of the Junge Parameter [• x ($\theta_o > 70°$) Barbados; o + ($\theta_o > 70°$) USNS Hayes].

## 3.2 SUNPHOTOMETER ERRORS

The San Diego data were obtained with the same Volz multispectral sunphotometer used for several years at Science Applications International Corporation (SAIC), and periodically checked against a second single-channel sunphotometer (at SAIC) manufactured by Eppley Laboratories for NOAA. This procedure described previously[3], was used both before and after the period of data at San Diego, viz., October 1982 and October 1983, and showed good agreement. However, subsequent more detailed checks from February through May 1984 showed poor repeatability from day to day, and sometimes during the day, indicating that one or both of the sunphotometers were malfunctioning. Some Langley plots were also obtained, but due to varying atmospheric conditions, they were of poor quality. However, these plots together with the inter-instrument comparisons suggested that the Volz sunphotometer was behaving erratically in the 500 nm channel in the February to May 1984 period.

These results do not prove that the sunphotometer was malfunctioning during the 1982-83 data period. However, considering the poor results obtained under near-ideal conditions, discussed in Section 3.1, it is believed that the sunphotometer was not working correctly during that measurement period.

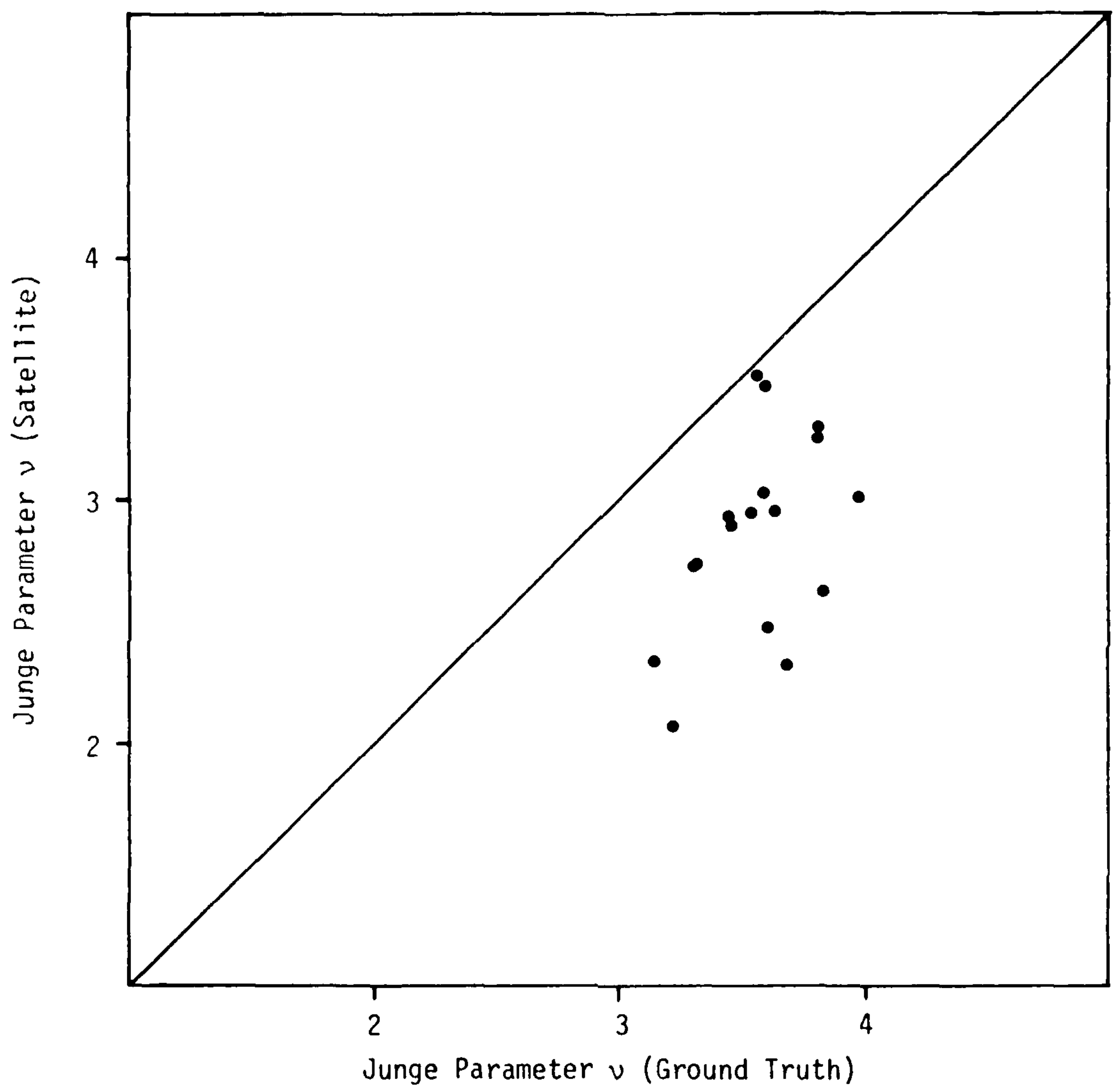


Figure 8. Comparison of NOAA-7 and Ground Truth Measurements of the Junge Parameter at San Diego (Closest Pixel).

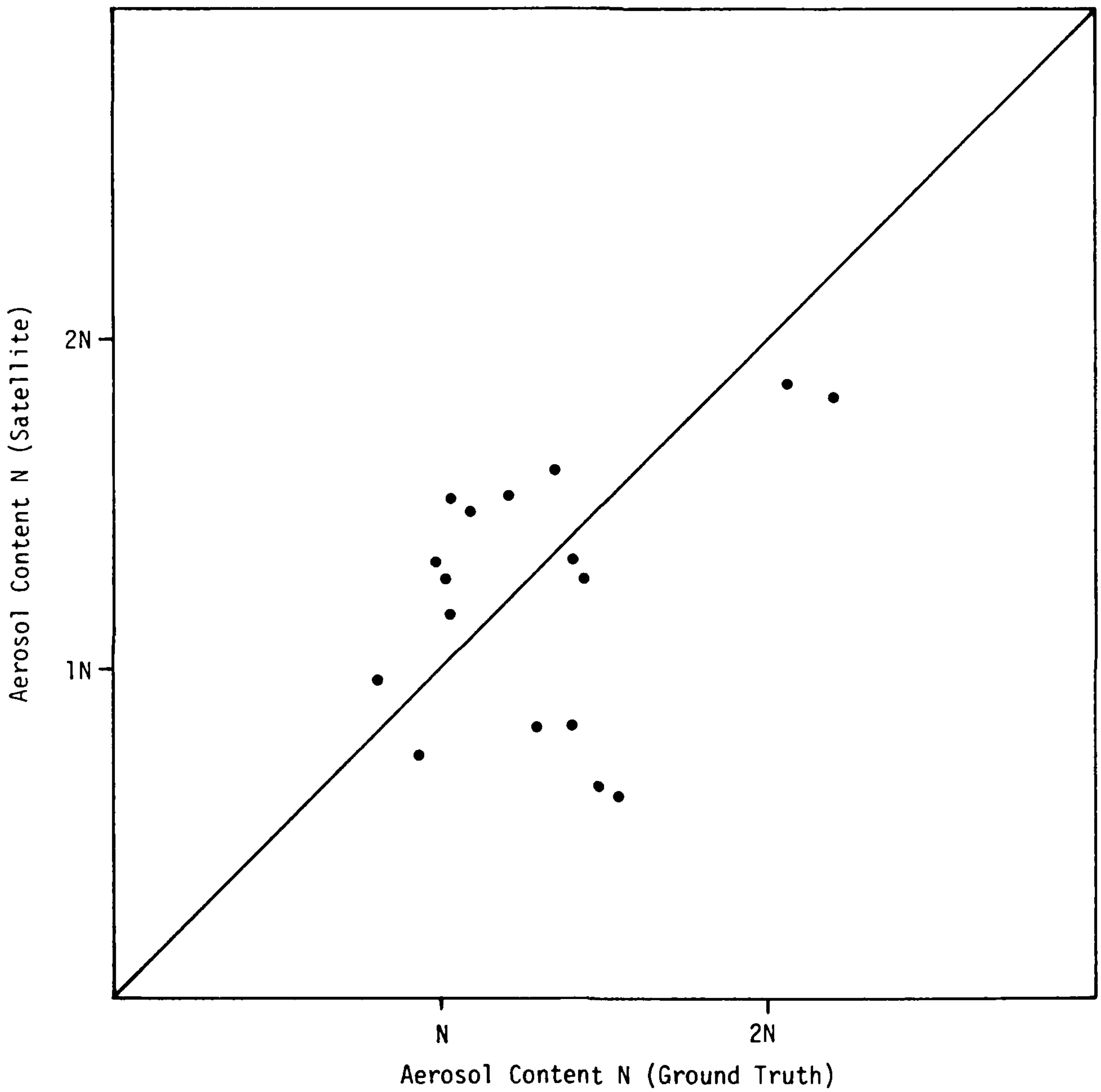


Figure 7. Comparison of NOAA-7 (TLU2) and Ground Truth Measurements of Aerosol Optical Thickness at San Diego (Closest Pixel).

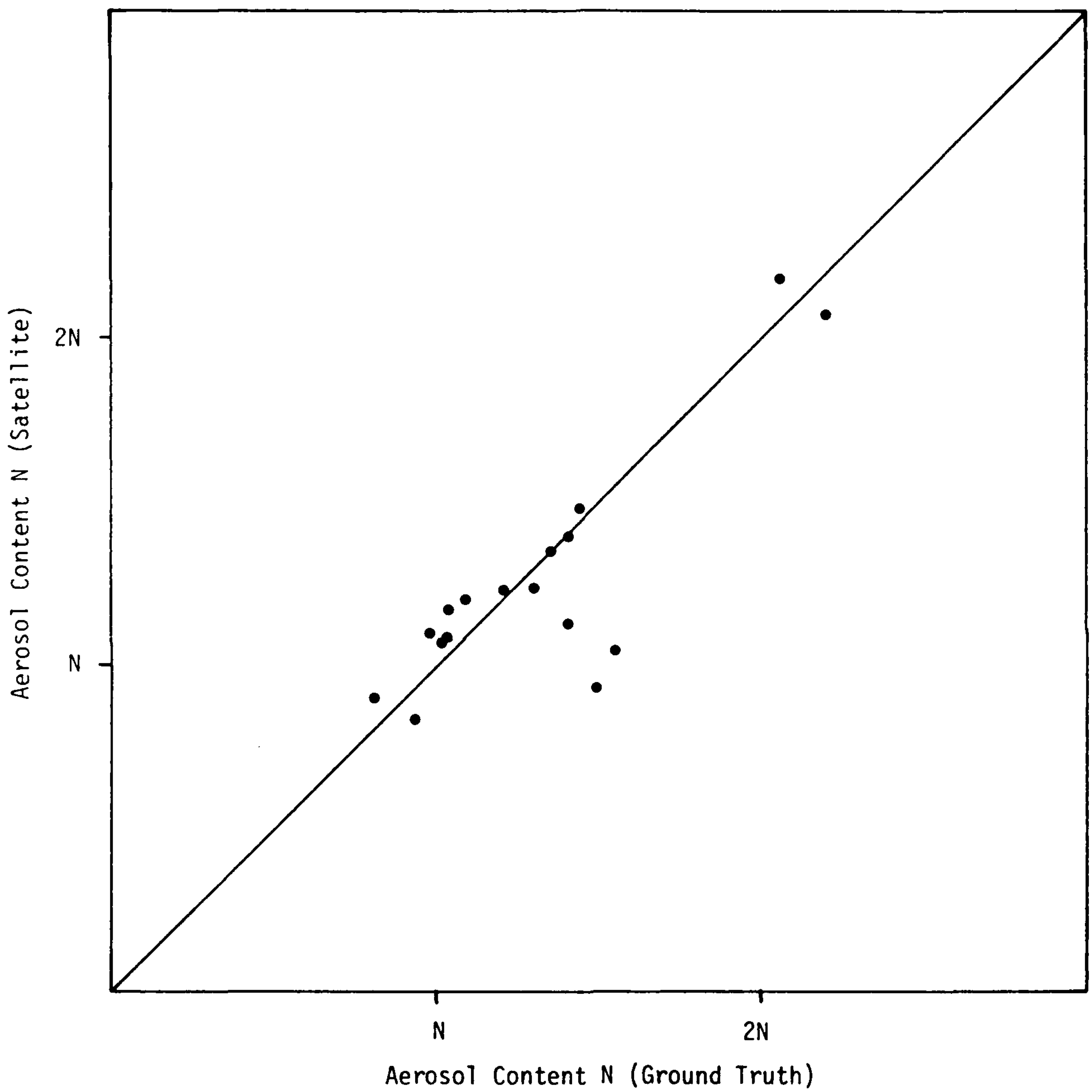


Figure 6. Comparison of NOAA-7 (TLU1) and Ground Truth Measurements of Aerosol Optical Thickness at San Diego (Best Pixel).

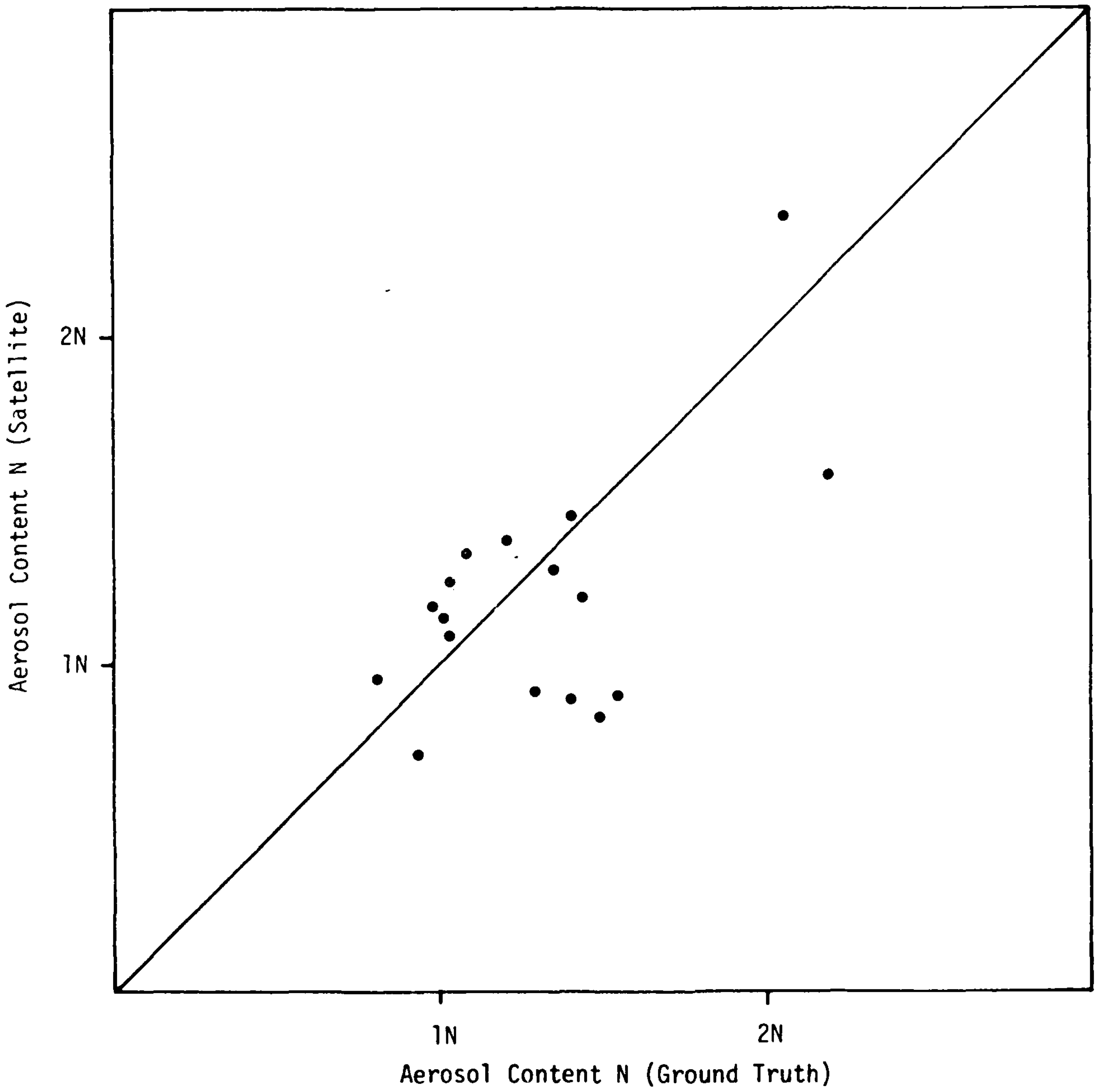


Figure 5. Comparison of NOAA-7 (TLU1) and Ground Truth Measurements of Aerosol Optical Thickness at San Diego (Closest Pixel).

Table 3. Results for 1982-83 Śan Diego Measurements.

| Date | Channel 1 | | Channel 2 | | View Angle $\theta$ | Sun Azimuth Angle $\phi$ | Sun Zenith Angle $\theta_o$ | TLU1 | TLU2 | | Ground Truth | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Albedo | Corrected Radiance ($mw/cm^2/\mu m/sr$) | Albedo | Corrected Radiance ($mw/cm^2/\mu m/sr$) | | | | N | N | $\nu$ | N | $\nu$ |
| 9/22/82 | 3.5 | 2.37 | 2.1 | 0.75 | 19.0 | 157.9 | 50.8 | 1.57 | 1.82 | 2.63 | 2.20 | 3.83 |
| 9/30/82 | 3.4 | 2.31 | 2.1 | 0.70 | 26.8 | 156.3 | 54.3 | 1.34 | 1.47 | 2.84 | 1.09 | 3.15 |
| 10/01/82 | 2.5 | 1.83 | 1.5 | 0.48 | 6.8 | 154.8 | 52.6 | 1.17 | 1.32 | 3.00 | 0.98 | 3.98 |
| 10/18/82 | 2.5 | 1.81 | 1.6 | 0.52 | 0 | 180.0 | 57.6 | 1.37 | 1.52 | 2.95 | 1.21 | 3.64 |
| 12/06/82 | 3.4 | 2.25 | 2.3 | 0.77 | 19.0 | 141.2 | 68.4 | 2.36 | 2.36 | 3.51 | 2.06 | 3.56 |
| 1/14/83 | 3.7 | 2.40 | 2.1 | 0.71 | 53.7 | 141.0 | 69.6 | 0.95 | 0.96 | 3.47 | 0.81 | 3.60 |
| 2/01/83 | 3.1 | 2.10 | 1.9 | 0.61 | 35.3 | 142.0 | 63.3 | 1.20 | 1.27 | 3.25 | 1.44 | 3.82 |
| 2/16/83 | 4.7 | 2.93 | 2.8 | 0.97 | 54.5 | 147.0 | 62.6 | 1.08 | 1.16 | 2.73 | 1.03 | 3.32 |
| 2/19/83 | 2.5 | 1.79 | 1.6 | 0.51 | 5.6 | 145.7 | 56.0 | 1.25 | 1.51 | 2.72 | 1.03 | 3.31 |
| 3/12/83 | 5.1 | 3.17 | 2.6 | 0.91 | 60.8 | 156.2 | 58.9 | 0.72 | 0.71 | 3.30 | 0.93 | 3.82 |
| 3/15/83 | 3.0 | 2.07 | 1.8 | 0.57 | 20.6 | 154.6 | 51.5 | 1.14 | 1.27 | 2.89 | 1.02 | 3.46 |
| 3/29/83 | 5.1 | 3.19 | 3.8 | 1.07 | 56.2 | 163.2 | 54.5 | 0.84 | 0.64 | 2.47 | 1.49 | 3.61 |
| 4/01/83 | 3.0 | 2.09 | 1.9 | 0.62 | 10.6 | 161.8 | 47.0 | 1.28 | 1.60 | 2.32 | 1.35 | 3.69 |
| 4/07/83 | 4.4 | 2.84 | 2.5 | 0.84 | 47.5 | 166.7 | 51.2 | 0.89 | 0.82 | 3.03 | 1.41 | 3.59 |
| 4/08/83 | 4.5 | 2.89 | 2.8 | 0.94 | 34.1 | 166.4 | 48.7 | 1.45 | 1.33 | 2.93 | 1.41 | 3.45 |
| 4/14/83 | 6.0 | 3.62 | 3.7 | 1.32 | 60.1 | 170.5 | 53.3 | 0.90 | 0.61 | 2.07 | 1.55 | 3.22 |
| 4/16/83 | 3.8 | 2.53 | 2.2 | 0.73 | 37.5 | 170.3 | 48.0 | 0.91 | 0.82 | 2.94 | 1.30 | 3.54 |

# 3.0 ANALYSIS OF 1982-83 SAN DIEGO DATA

In order to remove two of the uncertainties found in the Barbados and USNS Hayes data set, multispectral ground truth measurements were taken at San Diego always within two minutes of the time of the NOAA-7 overpass, and only in clear skies. Thus the effects of atmospheric inhomogeneities and undetected clouds, discussed in Section 2.2, were essentially eliminated. Data were obtained for nineteen overpasses, and were analyzed using both the TLU1 and TLU2 procedures. The results are given in Table 3, and in Figs. 5-8.

## 3.1 DISCUSSION OF RESULTS

The results for TLU1 in Fig. 5 are not as good as expected particularly since the ground truth measurements indicated an average value of $\nu$ close to 3.5 as used in TLU1. Improvement is seen in Fig. 6 when the best pixel is used, but there is little justification for the use of the best pixel in this data set since the measurements are essentially coincident and there were cloud-free conditions. It is believed that the poor results in this data set are due to problems with the sunphotometers used for the ground-truth measurements as discussed below.

The optical thickness results for TLU2 are shown in Fig. 7, and as found previously[1] for the Midway data, the errors are larger than for TLU1. This is in spite of the fact that the water vapor correction for the Channel 2 radiance was determined from the actual radiosonde soundings for San Diego on the day of the measurements. The correction factor ranged from 0.85 to 0.92 with an average value of 0.88, compared to the value of 0.86 used in the absence of water vapor measurements[4].

The results for the size distribution parameter measurements using TLU2 are given in Fig. 8, and show that the AVHRR apparently underestimates the $\nu$ value. However, since there is uncertainty in the sunphotometer data, as discussed below, no significance is attached to this result.

apparent sunphotometer errors. It would be of great interest to obtain a set of reliable ground-truth measurements during a Saharan dust episode to resolve this discrepancy. It should be noted that for a reliable data set obtained in 1980 by the author at San Diego[4], where $\nu$ is typically ~3.5, the rms difference in N using TLU1 was found to be only 0.07, i.e., very close to that predicted for the first three error sources.

In theory, the $\nu$ effect in TLU1 is, of course, minimized by the use of TLU2 which determines $\nu$. However, better ground truth than the B and H data set must be obtained to verify this in locations where $\nu$ is significantly different from 3.5.

the rms error in comparing the AVHRR and ground truth values is $(0.12^2 + 0.05^2)^{1/2}$, i.e. 0.13, which is approximately twice the TLU1 error.

Analysis of the B and H data given in Figs. 1 and 2, ignoring the three points with very large errors, shows that the root-mean-square difference between the AVHRR and ground truth values of N is 0.16 for TLU1 and 0.29 for TLU2, i.e. the TLU 2 error is approximately twice the TLU1 error as predicted above. However, the magnitudes of the errors are much larger than predicted for the first three error sources. Following the same arguments as used for the errors in $\nu$, it appears that the other error sources contribute 0.15 to the difference in N using TLU1, and 0.26 using TLU2.

Another error source must be considered in the determination of N with TLU1. This error source occurs due to the fact that TLU1 assumes $\nu = 3.5$, whereas the real value may be quite different, as at Barbados where $\nu \sim 2$. It was shown previously[3] that a value of $\nu$ different from 3.5 that is used in TLU1 can result in either a positive or negative error in the estimated value of N, depending on the viewing and sun angles.

For the Barbados data set this error results in an overestimation of N in 14 cases by up to 0.41, and an underestimation by up to 0.41 in the other 8 cases; the root-mean-square error is 0.27. The error for the USNS Hayes set (where $\nu \sim 3.5$) is negligible, so that the resultant rms error for the B and H data set is 0.25. This single error is significantly larger than the 0.16 total error actually found for B and H. This difference is not readily explained. If the refractive index of the aerosol is smaller than the value of 1.5 assumed in TLU1, then N would be underestimated, thus compensating for the general overestimation due to the $\nu$ effect. However, there is no evidence (J. Prospero, University of Miami, Private Communication) that the Saharan dust particles, which cause $\nu \sim 2$ at Barbados, would be significantly modified (e.g. by water condensation) to have a lower refractive index at Barbados. Another possible explanation is that the non-spherical shape of the Saharan dust particles is compensating for the $\nu$ effect, although this is unlikely since TLU2 gives reasonable $\nu$ values. A third possibility is that the actual errors at Barbados were reduced when the data set was adjusted to correct for the

errors are additive, giving a total of 0.52 for the predictable errors in the AVHRR estimate of $\nu$. Now, the mean ground-truth N value for the B and H data set is 1.13 N, so that from Equation (4) in the previous report(1), the uncertainty in the ground-truth value of $\nu$ is 0.13. Thus for the first three error sources listed above, the total error is $(0.52^2 + 0.13^2)^{1/2}$, i.e. 0.54.

The root-mean-square difference between the AVHRR and ground truth values of $\nu$ was found to be 0.66 for the B and H data set, which is higher than the 0.54 attributable to the first three error sources. Thus, it appears that the other uncertainties contribute $(0.66^2 - 0.54^2)^{1/2}$, i.e. 0.38, to the observed differences between the AVHRR and ground truth values of $\nu$. Of course, in an operational system, only the uncertainties in undetected clouds and in the ocean surface reflectance will be of concern, and should be significantly less than 0.38. It was hoped to make a better estimate of these errors using the 1982-83 San Diego ground-truth measurements (obtained by the author at the exact time of the NOAA-7 overpass). However, as discussed later, there were uncertainties in the data set, probably due to sunphotometer problems.

In summary, for an operational system in which the atmospheric water vapor content is known, the rms error in $\nu$ is likely to be somewhat greater than the 0.38 due to the AVHRR noise. However, if observations are restricted to viewing away from the nadir, i.e. to higher radiance values, this error will significantly decrease by about 0.10 (see Section 2.1) so that an rms error of about 0.30 in $\nu$ may be achievable.

### 2.2.2 Uncertainty in N

It was found in Section 2.1 that the noise in AVHRR Channel 1 results in an rms error of 0.03 in N when TLU1 is used. The sunphotometer can measure N with an uncertainty of 0.05, so that the total rms error in comparing the AVHRR and ground-truth values, for the first and third error sources (there is no water vapor effect in Channel 1) listed above, is $(0.03^2 + 0.05^2)^{1/2}$, i.e. 0.06. For the TLU2 code, the AVHRR noise and the water vapor effect in Channel 2 result in an error of 0.12 in N, so that

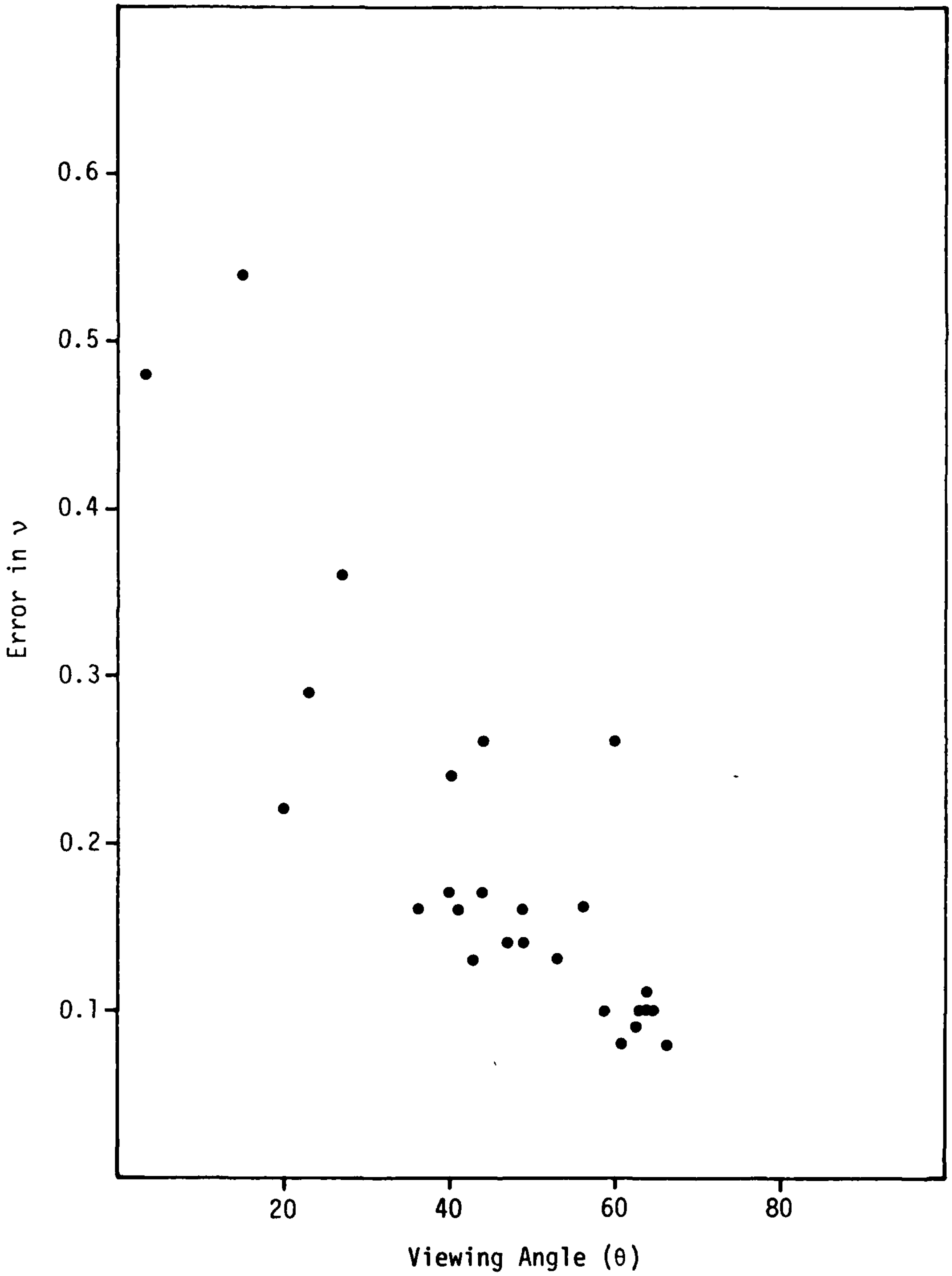


Figure 4. Variation of Error in ν, Due to Channel 2 Error, With Viewing Angle (From Table 1).

It should be noted that the AVHRR sensor noise is a large percentage of the signal level for near-nadir viewing, and results in larger $\nu$ errors as seen in Table 1 and in Fig. 4. If the five cases with $\theta < 30°$ are ignored, the rms error in $\nu$ decreases from 0.38 (see Table 2) to 0.28. The results in Tables 1 and 2 also show that the errors in $\nu$ are about the same regardless of which channel the radiance error occurs in. If the cases of near-nadir viewing, where large $\nu$ errors are observed, are ignored, it is seen that the errors in N are smaller for errors in Channel 2 than in Channel 1.

It was also found that the Channel 1 radiance error produces an rms error of 0.03 in N using TLU1 compared to 0.04 using TLU2; TLU1 also showed a smaller error in comparison with the ground truth(1). These differences between TLU1 and TLU2 are attributed to the fact that an incorrect $\nu$ determined by TLU2 results in an error in N.

## 2.2 COMPARISON OF OBSERVED ERRORS AND PREDICTED ERRORS

The differences between the ground-truth and AVHRR values of N and $\nu$ are due to (1) AVHRR noise, (2) uncertainties in the atmospheric water vapor content, (3) sunphotometer errors, (4) spatial and temporal inhomogeneities in the atmosphere (the sunphotometer and AVHRR sample the atmosphere through different paths and at different times), (5) undetected small clouds in the AVHRR field of view, and (6) uncertainties in the ocean surface reflectance. Estimates of the first three error sources were made in the previous report(1), so that a comparison of the observed and calculated errors will give some insight into the magnitude of the other uncertainties. It was shown previously(1) that the ozone variation may be neglected in the B and H data set.

### 2.2.1 Uncertainty in $\nu$

The AVHRR noise was shown in Section 2.1 to result in an rms error of 0.38 in $\nu$ for the B and H data set. The rms water vapor correction error for the B and H set was found to be 1.8% which gives an $\nu$ error of 0.14 (by linearly scaling the result for 3% in Table 2). It was shown that these

Table 2. Summary of TLU2 Errors in N and $\nu$.

| Error Source | $\Delta N$ (rms) | $\Delta \nu$ (rms) |
|---|---|---|
| 0.05% Albedo Channel 1 | 0.04 | 0.20 |
| 0.05% Albedo Channel 2 | 0.04 | 0.20 |
| 3% Radiance (Due to $H_2O$) Channel 2 | 0.05 | 0.24 |
| Combined (With $H_2O$) | 0.12 | 0.62 |
| Combined (No $H_2O$) | 0.07 | 0.38 |

Table 1. Results of TLU2 Error Analysis for Barbados and USNS Hayes Data.

| Date | Observation Time Minus Satellite Time (Minutes) | Channel 1 Albedo | Channel 2 Albedo | View Angle $\theta$ | Sun Azimuth Angle $\phi$ | Sun Zenith Angle $\theta_o$ | Channel 1 +0.05 Error | | Channel 2 -0.05 Error | | Channel 2 -3% $H_2O$ Error | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | $\Delta N$ | $\Delta\nu$ | $\Delta N$ | $\Delta\nu$ | $\Delta N$ | $\Delta\nu$ |
| 7/27/80 | -2 | 2.6 | 1.8 | 40.4 | 157.0 | 67.8 | 0.02 | 0.20 | -0.02 | 0.24 | -0.02 | 0.26 |
| 7/28/80 | 10 | 6.2 | 4.2 | 62.8 | 157.0 | 72.9 | 0.05 | 0.09 | 0.02 | 0.09 | 0.06 | 0.23 |
| 7/31/80 | 6 | 2.5 | 2.0 | 19.9 | 157.0 | 65.0 | 0.00 | 0.20 | -0.06 | 0.22 | -0.07 | 0.25 |
| 9/24/80 | 31 | 2.7 | 1.7 | 44.1 | 178.0 | 68.1 | 0.04 | 0.20 | 0.02 | 0.26 | 0.01 | 0.02 |
| 8/14/80 | 50 | 3.3 | 2.3 | 36.1 | 161.8 | 67.1 | 0.02 | 0.13 | -0.02 | 0.16 | -0.04 | 0.21 |
| 8/15/80 | 12 | 6.0 | 4.1 | 61.0 | 162.4 | 72.5 | 0.05 | 0.07 | 0.03 | 0.08 | 0.06 | 0.21 |
| 8/19/80 | 10 | 3.7 | 2.5 | 49.3 | 163.6 | 69.6 | 0.04 | 0.12 | 0.01 | 0.14 | 0.02 | 0.22 |
| 8/18/80 | -22 | 1.6 | 1.3 | 14.9 | 163.0 | 64.3 | -0.04 | 0.52 | -0.11 | 0.54 | -0.08 | 0.36 |
| 8/24/80 | 26 | 4.0 | 2.9 | 59.9 | 165.6 | 72.1 | 0.04 | 0.30 | 0.03 | 0.26 | 0.05 | 0.38 |
| 8/28/80 | 49 | 3.6 | 2.5 | 48.5 | 167.0 | 69.2 | 0.05 | 0.14 | 0.02 | 0.16 | 0.03 | 0.24 |
| 9/06/80 | 28 | 4.5 | 3.3 | 47.0 | 170.6 | 68.7 | 0.07 | 0.12 | 0.05 | 0.14 | 0.08 | 0.31 |
| 10/02/80 | 7 | 1.7 | 1.4 | 3.3 | 179.0 | 62.7 | -0.04 | 0.43 | -0.11 | 0.48 | -0.08 | 0.33 |
| 10/03/80 | 68 | 3.9 | 2.6 | 43.1 | 177.9 | 68.1 | 0.04 | 0.10 | 0.01 | 0.13 | 0.01 | 0.20 |
| 10/04/80 | 48 | 4.9 | 2.8 | 64.2 | 177.9 | 73.5 | 0.04 | 0.09 | 0.02 | 0.11 | 0.02 | 0.20 |
| 9/28/80 | -1 | 2.0 | 1.4 | 26.6 | 179.8 | 65.4 | 0.01 | 0.30 | -0.05 | 0.36 | -0.04 | 0.28 |
| 9/29/80 | 9 | 3.7 | 2.2 | 55.8 | 179.7 | 70.8 | 0.04 | 0.12 | 0.02 | 0.16 | 0.02 | 0.20 |
| 9/02/80 | 20 | 4.5 | 2.8 | 58.6 | 169.0 | 71.2 | 0.04 | 0.09 | 0.02 | 0.10 | 0.03 | 0.18 |
| 10/13/80 | 2 | 4.9 | 2.9 | 63.6 | 174.2 | 73.6 | 0.03 | 0.08 | 0.01 | 0.10 | 0.02 | 0.19 |
| 10/12/80 | -6 | 3.4 | 2.3 | 41.4 | 174.2 | 68.2 | 0.04 | 0.12 | 0.00 | 0.16 | -0.01 | 0.21 |
| 10/16/80 | -8 | 2.2 | 1.7 | 23.2 | 172.2 | 65.8 | 0.01 | 0.27 | -0.05 | 0.29 | -0.05 | 0.27 |
| 10/30/80 | -7 | 3.2 | 2.2 | 40.4 | 167.4 | 69.6 | 0.02 | 0.13 | -0.01 | 0.17 | -0.02 | 0.23 |
| 10/31/80 | 15 | 5.7 | 4.1 | 62.9 | 167.8 | 74.8 | 0.05 | 0.10 | 0.03 | 0.10 | -0.07 | 0.23 |
| 4/10/80 | 6 | 3.9 | 2.4 | 52.8 | 179.2 | 68.8 | 0.05 | 0.11 | 0.02 | 0.13 | 0.02 | 0.19 |
| 4/11/80 | 15 | 5.3 | 3.3 | 61.8 | 179.9 | 71.0 | 0.04 | 0.08 | 0.02 | 0.10 | 0.04 | 0.18 |
| 4/12/80 | 34 | 5.8 | 3.4 | 66.4 | 179.3 | 72.3 | 0.03 | 0.08 | 0.02 | 0.08 | 0.03 | 0.18 |
| 4/19/80 | 54 | 3.8 | 2.0 | 43.9 | 178.0 | 64.6 | 0.04 | 0.12 | 0.01 | 0.17 | 0.00 | 0.20 |

## 4.0 CONCLUSIONS AND RECOMMENDATIONS

The error analysis of the two-channel technique has shown that the AVHRR noise will result in root-mean-square errors of about 0.40 in $\nu$, and about 0.08N in N. These errors will be increased due to the effects of undetected clouds in the field of view and variations in the ocean surface reflectance. Based on an analysis of the Barbados and USNS Hayes, these environmental errors could be of the same magnitude for $\nu$, and larger for N. However, because of uncertainties in the data set there is uncertainty in these estimates of the environmental errors. An effort was made to obtain a good data set at San Diego to clarify these errors. However that data set was also of uncertain quality due to apparent sunphotometer problems. As a result, further clarification of the environmental errors was not possible.

It is recommended that good data sets be acquired using a well-calibrated state-of-the-art sunphotometer, with emphasis on regions where a large range of $\nu$ values might be observed, e.g., San Diego where generally $\nu \sim 3.5$, and Barbados, where Saharan dust outflows occur in the summer, giving $\nu \sim 2$.

## 5.0 REFERENCES


1. M. Griggs, Satellite Measurements of Atmospheric Aerosols, Annual Report. Contract N00014-17-C-0489 (November 23, 1983).

2. M. Griggs, Satellite Measurements of Maritime Aerosol Parameters, Final Report. Contract N00228-82C-6199 (March 10, 1983).

3. M. Griggs, Satellite Measurements of Atmospheric Aerosols, Annual Report. Contract N00014-17-C-0489 (November 14, 1980).

4. M. Griggs, Satellite Measurements of Atmopsheric Aerosols, Annual Report. Contract N00014-17-C-0489 (August 26, 1981).

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